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THE general use of the word biology in this country dates from a period scarcely more remote than ten or twelve years ago, and, even at the present day, in spite of the fact that a good many of our schools and colleges announce courses on the subject, and even the newspapers occasionally discuss its popular aspects, the question is not unfrequently asked by persons generally well informed, What is biology? The question is not easily answered, for, if we say that biology is nothing but the essence of botany and zoölogy—which is the fact—then the inquirer not unreasonably asks why we now hear so much about biology, while we formerly heard only of botany and zoology, and the inference is that biology is nothing but a fine-sounding word newly coined to take the place of what used to be called natural history. This is in a certain sense true, but biology means rather natural history as it is, than natural history as it used to be, studied. It is to natural history—I use the terms as adopted in this country, without considering what their original application may have been—it is to natural history what reform is in politics: as reform seeks to elevate existing parties by forcing them to correct abuses and to infuse new life by discussing questions of the day rather than past issues, so, under the guise of biology, the attempt has been made to infuse new life into natural history by substituting for the exclusively descriptive study of plants and animals a broader science which shall include also histology, physiology, and the history of development.

* Read before the Society of Naturalists of the Eastern United States.

As a protest against a too narrow view of natural history, biology attracted a large number of advocates in this country, who hoped that the new, or, if you please, the newly named science, would not only enlarge the views of professional and amateur naturalists, but would also furnish a valuable aid in the education of the young. It is not my purpose to speak of the changed aspect of professional and expert studies, viewed from a biological stand-point, but merely to consider the effect which has been produced on elementary instruction in colleges and schools. Within the last ten years a large number of books and papers has appeared in print, intended to show teachers how to teach and students how to study plants and animals. Some of them are excellent, and certainly, as far as books go, they leave little to be desired. They all start with the advice that a beginner should study plants and animals themselves, rather than what has been written about them. In other words, the first thing is to learn to observe. In inculcating the importance of observation the modern biologists are only repeating the advice of the naturalists of the old school, although it must be said to the credit of the former that they have insisted upon observation with a frequency and urgency previously unknown. But how is one to begin? The biological method suggests a careful study of a few types which will give the beginner a general acquaintance with the essential structure of both the animal and vegetable kingdoms; whereas, by the older method, it was the fashion to study rather minutely the external characters of a considerable number of species of certain groups of plants or animals, and the general view of the two kingdoms was obtained, if obtained at all, from lectures, and not from an actual study of specimens in the laboratory.

As I have said, the new mode of study has been more or less in vogue in our leading schools and colleges for about ten years, and we ought to ask, with what success? Has it accomplished what was expected? Or, if not, what is the reason? It has been my lot to teach one branch of biology to college classes, and, as my experience seems to me to show that, in some respects, the result is disappointing, I should like to state some of the difficulties which have presented themselves in my case, not that I have lost faith in the system at all, but because my experience apparently shows that considerable improvement must still be made before the best results can be attained.

The students who come under my charge, about thirty-five annually, are probably in intelligence and industry good representatives of the average student as found in our colleges. They come from all parts of the country, and while many of them have been fitted for college at the different classical schools, where the great object is to prepare boys to answer certain examination questions, education as such being considered of very slight importance, others are fitted in schools where natural science is ostensibly taught, and others still

come from distant colleges and technical schools. The course is strictly an elementary one, and no previous knowledge of botany or zoölogy is required. As a fact, a considerable number of the class have studied botany before entering college, and, as others have not, I am able to compare the results of different methods of study in the fitting-schools.

After a few directions concerning the use of the compound microscopes placed before them, some simple material is given them to examine. Considering the large number of good books which insist upon proper training of the observing powers, and knowing how extensively they are read by teachers, I might hope that, at least, a good share of my class would know how to set to work. But what is the case? The first question asked by about three fourths of any class is sure to be, "What do you wish me to observe?" What a question! Is this the result of several years' training, that a young man eighteen years of age, or older, must be told just what to observe when a preparation is put before him? Has it come to this, that, while a boy eight or ten years old will examine with interest objects placed before him, a college student will not examine a preparation until he has been told exactly what he is to see in it? When I reply, "I wish you to examine whatever there is to be seen in your preparation," there is a look of astonishment, sometimes shading off into dismay. That an instructor should expect students to look at an object before them and make out its structure, or attempt to make out its structure, by themselves, seems to them something quite unheard of, and they evidently feel that there is a certain meanness attaching to one who will not tell them just what they must see. It has never entered their heads that, while an instructor may be able to tell them what he himself sees in the object to be studied, he can not tell them what they will see in it, and that it is only after they have studied the object for themselves and attempted to form an idea of its structure that he can explain what is obscure or correct what is erroneous. Evidently the greater part of the students regard the objects placed before them as so many diagrams, and the instructor is to serve the same purpose as the "explanation of figure so-and-so" in a text-book.

The question naturally arises, where were those who ask, "What do you wish me to observe?" fitted for college? Do they all come from the classical schools, where the only natural history studied is a three weeks' cram of Gray's "How Plants Grow"? Unfortunately, they do not. Nothing better, perhaps, could have been expected from schools where nearly all the instruction is confined to languages, and where the inquiring spirit and fondness for observation natural to children, are suppressed to a great extent. Some of the students in question have come from schools, or worse still, from colleges, where natural history is taught, and where use is made of some of the excellent books to which I have already referred. It is evident that a good book is

not enough, for there can be no doubt that many teachers take the very books which emphatically urge the necessity of observation, and use them just as they would a grammar, or a school history, so that the observation, in this case, may be said to consist in observing what is said on a certain page of a certain book, and not in watching any plant or animal.

Supposing that I am correct in believing that about three fourths of a class ask the question, "What do you wish me to observe?" there still remain one fourth who do not ask the question. Among these are some who are by nature good observers, or who have been well trained, but the number of these is very small. The remainder consists of those who have already studied biology according to the very latest method with all the modern improvements. They do not ask what I wish them to observe, but, on the contrary, begin to lecture to me about the object under consideration and things in general. If I give them some yeast to examine, they tell me at once all about its history, and show me the spores which it seems necessary that the yeast should have to make it agree with the books. It makes no difference if I substitute a quantity of starch for the yeast. If I only call it yeast, it will have all the book-marks of yeast. This over-educated class of young men is very entertaining, but very hard to teach. Everything is grist to their mill. For them the ubiquitous air-bubble makes a simple but sufficient nucleus, if it is necessary to have a nucleus, or it will serve equally well as a spore if spores are desired. Nothing is so insignificant that they can not apply to it a big name, and no theory is so complex that it can not be dragged in to explain the most self-evident cases.

I have said enough to show that, unless my experience is an exceptional one, in spite of all the talk on the subject, boys at school are not taught to observe as they should be, and that even those teachers who use good text-books frequently use them as means of imparting facts easily and quickly by the old method, rather than as an aid in the scientific training of the faculties which must form the basis of any serious study of biology. One fact has surprised me. Some of the best observers among my students have been persons who fitted at the classical schools, where the training is exclusively linguistic and mathematical. To be sure, they have been considered a bad lot by some of their instructors, and I presume that they paid little attention to their studies at school. Perhaps it is in consequence of this very neglect that their natural powers of observation have been less impaired than those of their fellows who have learned more and seen less.

It seems a great pity that students should come to college so ill-fitted, as are the majority, to undertake biological work. But we must accept things as they are, and there is no use in attempting to take the second step before the first has been taken. If the school can

not or will not teach observation, then it must be taught in college, no matter if it does seem to be child's work. In colleges, however, it is absolutely impossible to find the time or the means for training every one to become an observer, and we are obliged to distinguish between two different classes of persons in arranging courses in biology. The first and much the larger class in Eastern colleges includes all those who are preparing themselves for literary, legal, and other similar pursuits, and who wish to know the most important facts about animal and plant life, but who, after they have entered college, can not afford the time to train themselves for strictly scientific studies. This class must of necessity be taught by lectures and, perhaps, a few demonstrations, and, as far as the method is concerned, it is the same as that pursued in teaching literature, history, or other subjects in which general information is sought. Nothing further need be said with regard to biological instruction intended for this class of students, for in several of our colleges the instruction of this kind is distinctly good and constantly improving.

The second class of students includes those who are intending to become professional naturalists, teachers of natural science, or medical practitioners; in short, all who need to know plants and animals practically and the methods of biological investigation. Of course, every naturalist and teacher of natural science should have a practical acquaintance with plants and animals. So, too, should every respectable physician be trained in methods of biological study. To him every patient should be a field of research. By his own powers of observation he is to find out signs and symptoms of which the patient can not or will not give information. Merely listening to lectures, however entertaining or full of information, is not enough for this class of students. Work in the laboratory is necessary, and, in my opinion, that work had better precede any detailed course of lectures.

Being myself merely a botanist, I can only speak of the way in which plant-life may be taught, but, as far as the method of instruction is concerned, what is true of botany is, I presume, essentially true of zoölogy. Considering the age of college students, and the necessity of using the compound microscope, if one intends to make a practical study of biology, it seems to me best that the instructor should begin with some simple form like yeast or a unicellular alga.

There are other reasons besides, which make it desirable to begin with the smaller forms which can only be studied with the microscope. As it is necessary, under present conditions, to begin by teaching a student how to observe for himself, it is better to use for this purpose small forms which he has probably never seen before, or, if he has read books on biology, a mixture of several small forms which he can not recognize from pictures. The plan of recommending any text-book in the beginning is very injurious. If books are

used, by far the greater part of any class will, from mere force of habit, commit the contents, and then imagine they see everything mentioned in the books and nothing more. After they have been trained to observe, they may be allowed to consult books, but not before. What is true of books is true of lectures on objects taught in the laboratory. The students always wish to have the lecture first and see the object afterward. It seems to them to lighten the work, but they fail to recognize, what is evident to the instructor, that they are not learning so much or so well.

Again, few students have any proper conception of solid bodies, and, to train them on this point, nothing is so good as some opaque body which has to be studied by microscopic sections. For this purpose I use pieces of pine-wood which are given to the class early in the term, just as soon as they have acquired a little facility in the use of the microscope. A piece large enough to show the annual rings is given to each student, who, by looking at the rings, can tell from what part of the trunk his piece came. After some simple directions about cutting, the student is told to make sections in three directions: at right angles to the trunk, and in the directions of the radius and tangent, and in the order named. After they have made and drawn the first section, if asked what they think is the structure of the wood, almost all of them will at once say that it is composed of square cells. If one asks what they mean by square cells, they say cells shaped like dice. In classes of from thirty to forty persons, I have never found more than four or five students—in one class there was only one—who knew enough to say that they could not tell what the structure of the wood was until they had seen sections in other directions. The cross-section made, they proceed to the radial section. Having already made up their minds from the cross-section that the wood is formed of cubical cells, the radial section, with its long tubes showing the peculiar disk-like markings of coniferous wood on the walls, utterly confounds them; and it requires considerable time before they give up the attempt to make what they see in the radial section agree with the cubical cells which exist only in their own imaginations, and realize that it is only by mentally combining the transverse and radial sections that they can arrive at any correct conception of the structure of the wood. Finally, the disk-like markings are to be explained. After trying ineffectually to pass them off as nuclei, vacuoles, or other structures which they have heard are to be found in vegetable cells, they are finally induced to see whether they can not find any traces of them in the other section, and so, slowly, they make out their real nature.

No work which I ever have to do as an instructor is so utterly dreary as that of forcing students to have a correct conception of solids. It is really a lesson in solid geometry; a subject which, as we all know, many persons can only learn with great difficulty. But,

difficult or not, the training in this direction is so important that it warrants the amount of time and labor spent. As a rule, I fear, classes do not see why I give them pine-wood to study. They dislike the work very much, and feel that they have learned comparatively little. If the only object were to know the structure of pine-wood, I could tell them that in a few moments. What they have learned, without being aware of it at the time, is the way to examine solid, opaque bodies, a category including by far the greater part of biological structures. Once done with the pine-wood, progress is always comparatively rapid, and I can only conclude that the classes are strengthened by the work done on the wood.

I need not occupy your time with any further account of what can best be taught in laboratories to beginners. There is nothing to be said against the plan laid down in the manuals in common use, provided the student is not allowed to follow it mechanically, and look at nothing which is not mentioned in the book. A good instructor is, of course, so well informed about the subject he teaches that he can turn almost any material to account. In my own case, it would be very inconvenient to furnish the same material year after year; but almost anything can be used to illustrate the typical modes of growth and reproduction in the vegetable kingdom, which is what the beginner needs to know.

There are, however, a few points to be considered, which bear on the relations of the instructor to the student in college classes. It should be borne in mind that one is not dealing with school-boys, but with young men who, if they are as ignorant of biology as school-boys, have, however, learned other things, and whose development, obtained from studies at school, so far from making them better able, has, in the majority of cases, made them only the less fit to take up biological studies. If they have much to learn, they have also something to unlearn. They have been taught to rush at a fact as a bull rushes at a red rag—for the purpose of tossing it away immediately. The position of the instructor is not an easy one. He is under constant restraint, as he must not tell the student, but must, if possible, make the student tell him, the structure of what lies before him. He is in the position of a boxing-master, who might easily floor his pupil by a single blow, but who must, by the exertion of great prudence and skill, contrive to let the pupil hit him. By a judicious series of questions, suggestions of possibilities or alternatives, the student may be kept in the right track and yet do all the work of advancing toward the truth himself. Under no circumstances should an instructor let a student, who is a beginner, discover what his own views are about any point to be studied. Although they may be wretched observers of natural objects, it does not follow that students are not good judges of human nature. Without any instruction they manage to become adepts in that direction. They often hope, by the

exercise of ingenuity in detecting allusions to what they are studying, in remarks carelessly made by the instructor, to find out what his pet ideas and theories are. And where is the instructor who is not pleased to find his own favorite opinions ardently, and, as it seems, independently indorsed even by a student?

Another difficulty is the almost universal habit which students have of using technical or semi-technical terms which, in reality, convey to them no idea whatever. They think they have comprehended the *thing* when they christen it with a high-sounding *name*, and they do not stop to ask themselves whether they understand what the name means. The student who called a hole in a cell-wall a bioplast was quite pleased with his achievement until he was asked what a bioplast was. The suggestion that a hole might, without any great violence to the English language, be called a hole, was timely if not pleasing. Evidently, for an educated man, the art of calling a spade a spade is difficult to acquire. Day after day, one is obliged to ask students to translate their lingo—I don't know what else to call it—into English. Frequently they can not. At length they begin to see that they are only deceiving themselves by using words which they do not comprehend to describe structures which they do not understand. It frequently happens that, after a student has described an object under the microscope in what he considers fine scientific language, he admits that he does not understand the structure of the object at all, but, on making him start over again, and describe it in plain English, he finds that it all comes out clearly enough. It is evident, for instance, that, so long as a student thinks he must call all round bodies in cells nuclei, he will soon have such a stock of nuclei on hand that he will be hopelessly confused, and the matter is not much improved if, as a last resort, he indiscriminately calls some of his superfluous nuclei vacuoles and others bioplasts. The tendency to use meaningless words is not, by any means, confined to biological students, but, in a laboratory where one is examining something definite, the evil should certainly be checked by frequent demands for English translations of verbose rubbish.

In giving you a somewhat detailed account of my own experience, gentlemen, I am probably saying nothing new to you. It is an old story, and perhaps a monotonous one. If I have spent considerable time in stating the difficulties in the way of college instruction, it is because I see that we must first have a clear conception of what the difficulties are before we can make any real progress. The most serious obstacle, it seems to me, is not so much that boys are not taught biology at school, as that they are not taught to observe, but are, on the other hand, taught to memorize text-books, and to regard education as the acquiring of facts in the most rapid and easiest way. It is a mistake to suppose that he is the best teacher who gives the most information in the shortest time with the smallest expenditure

of labor on the part of his hearers. Such a teacher fails in a most important respect. The pupil under his guidance becomes a passive recipient of knowledge, and is not trained to rely on himself or to become an active worker in any direction. Patting one on the back and saying, "Don't you see this?" and "Don't you see that?" does not tend to produce a very robust mental development. You can not make a boy a good mountain-climber by carrying him up the Mount Washington Railway, no matter at how rapid a rate; and, in ordinary life, there are many mountains to be climbed, up which there is no railway.

As far as I can judge from the qualifications of students who come under my instruction, the schools have within the last six or seven years made no perceptible progress in training the observing powers. The good advice given and the good text-books by competent authorities have not, as yet, produced any marked effect. As far as elementary training is concerned we are about where we were ten years ago. The college-instructor must still regard the student who studies under him as a school-boy whose capacity for observing and investigating natural objects has been blunted by a one-sided course of instruction at school. Hence we are still under the necessity in college courses of beginning at the very beginning, and, if there is any mistake in our colleges, it is that the instruction in biology is pitched in too high a key. For those who are to study practically animal and plant life it is better to stick to commonplace topics for a year or two, and insist upon the careful examination of living plants and animals, before proceeding to an elaborate discussion of theories which, however great their value to mature scientific minds, would easily lead a beginner into mere vague speculation. The distinction between lecture courses for the general information of those who are not intending to enter pursuits which demand practical training in biology and courses for those who do need such training should be carefully adhered to. Again, an instructor should not hurry with his elementary classes. Knowing how much there is to be learned, he naturally feels obliged to teach as much as possible. But it is better to be slow and sure in the beginning, and, if necessary, hurry at a later stage.

One serious difficulty under which our colleges labor in laboratory instruction is the lack of a sufficient number of suitable assistants. This is not usually because properly qualified assistants can not be obtained, but because they can not be obtained for the salaries which are usually paid. In teaching elementary classes of from twenty-five to fifty persons in branches requiring the use of the compound microscope, one assistant is not enough. To do the work properly, at least two, and, better still, three assistants are needed, supposing, as is generally the case, that all the work is done on three days of the week.

The question arises whether we are ever to expect that the elements of biology will be properly taught in schools. At present there

are very few schools where they are well taught, and information is lacking to show that the number is increasing. Good books exist, but books are only of secondary importance, and certainly good teachers are few indeed. The improvement in the quality of college graduates who could teach biology in schools, if there was any demand for it, gives room for hope. Under the present fashion of cramming for college there is not much to hope for in the ordinary fitting-schools, and it would be much better if they abandoned altogether the very palpable sham which they now call botany. More could probably be accomplished in the grammar and primary schools where there is more time, and where the pupils are of an age when they naturally feel interested in plants and animals. Of course, in such schools one should begin with the larger flowering plants and not attempt to use the compound microscope. Certainly, in schools in the country or in places where the children frequently see plants growing, botany, if well taught, would be admirably adapted for awakening and developing the spirit of observation and investigation. In large cities the case is somewhat different. There the children hardly ever see plants growing, and the expense of providing them with the few flowers shown at school is hardly warranted by the good derived therefrom. As the main object is to acquire the power of observing, I am by no means certain that, in large cities, physics, or at least mechanics, may not prove to be better adapted to the purpose than botany or zoölogy.